DESIGN CONSIDERATIONS FOR COLOR SUSTAINABILITY
IN THE INTERIOR SPACES OF HOSPITALS

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ABSTRACT

The art of coloring has many different aesthetic moods, criteria, and applications, in addition to different contrasting functions. Colors have purely scientific origins and rules that are directly linked to light. At the same time, color selection is a key element in interior design processes. Such strong properties give colors special importance to current local and global interest in interior design and to its relations to various dimensions of living. The quality of a visual environment can have a positive effect on an occupant's feelings of well-being inside interior spaces of hospitals and healthcare buildings; it can positively or negatively affect staff performance and patient recovery. On the other hand, the costs of maintaining efficiency in functionality among hospital staff and in patient treatment are considerable. Therefore, the maximization of performance through improved environments must be generally cost effective. In this context, this research intends to discuss lighting and color design in terms of sustainability at the early stages of interior design. A truly integrated set of lighting and color design standards is constructed to be based on a sustainable approach and tested. A general model is also formulated and a design toolkit is presented.

KEYWORDS: Color Physiology, Color Sustainability, Hospital Interior Design

1. INTRODUCTION

Color is a key player in creating accessible environments. Color should be taken into consideration as a basic tool in choosing materials and surface textures and for providing visual and tactile cues to help people who have poor vision to effectively use a healthcare building. Phenomena related to light affect the visual sensation of interior spaces. Color contrasts and shadows can present obstacles to recognizing some internal features of buildings. Lighting and color design should be integrated into the buildings design to allow the human eye to adapt to changes in lighting levels. Furthermore, colors should support the lighting effects that are required to achieve some design objectives and functions inside buildings.

In hospitals, the focus of this research, interior spaces should include some types of lighting effects that turns on automatically in emergency evacuation procedures. Furthermore, a relatively minor change to the color design or lighting of spaces can solve problems of abandoned areas. For example, extra lighting on walls with an accent color can brighten up a gloomy area. Color and lighting design integration is a key factor in solving many issues inside buildings, especially healthcare buildings. The psychological needs should be considered in design processes in addition to the physical and visual considerations that are important to hospital users.

2. RESEARCH OBJECTIVE

The main research objective is to extract possible design considerations for the use of color in terms of sustainability in interior design processes of hospitals' interior spaces and to improve performance and patient recovery inside hospitals, taking into consideration the psychological needs of users without overtly affecting the spaces' functionality, dynamics, and social aspects.

3. MATERIALS AND METHODS

The research is undertaken in two main phases. The first reviews the following issues that are critical in achieving the objectives of this research, mentioned in the preceding section:

- The latest modern technologies in the field of interior design.

- Similar applications using current software design tools that are based on the relationship between color, light, and positive energy of life

- The physical impact of patients' physical and psychological needs on interior design process.

- The impact of architectural requirements and complementary elements of interior spaces to improve the inside performance.

After a discussion of the main research issues and an analysis of related case studies, the design considerations of sustainable color design can be determined as the factors of creating positive, psychological, and social interior spaces. The second phase of the research is based on testing these design considerations through their application in related case studies. These applications rely on surveys and the results of applications using the program Autodesk Ecotect.
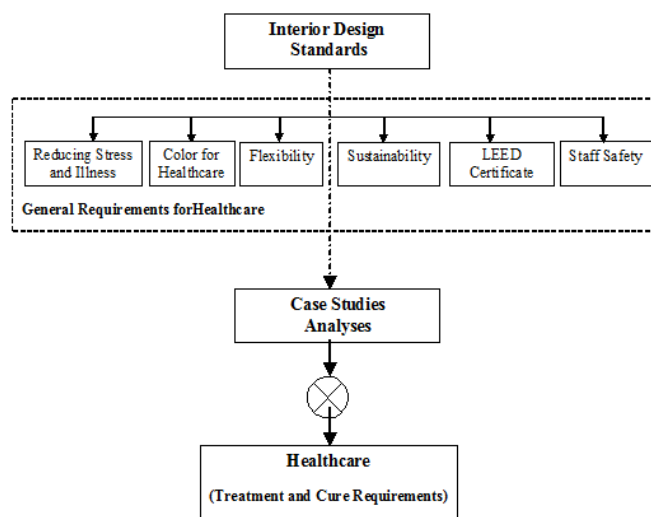
General Requirements for Healthcare

Figure 1: Research Outline and Methodology

4. RESEARCH BACKGROUND

Goodle noted that currently there has been great interest in the psychology of colors and material finishes and their impact on hospital users. The literature concerning sustainable development has addressed human needs as one of the three axes of sustainable development. Dalke and Hilary have defined the concepts of the sustainability of different

elements in interior spaces as one of the poles of sustainable development. For the healthcare industry, the issue of environmental impact is paramount. The profession is committed to doing no harm, yet many issues related to the design and operation of healthcare facilities contradict this principle tenet(Phillip Park & Park, 2013; Wittmann, 2009). This section discusses the following issues(Figure 2), treatment philosophies, as well as the environment, hospital users and their needs, the constructed environment and human health, design considerations to alleviate stress and illness, theories about color design and psychology, and sustainable design for healthcare. By the end of this section, a basic set of criteria for sustainable color design will be constructed, to be applied and tested as design standards in the following sections.
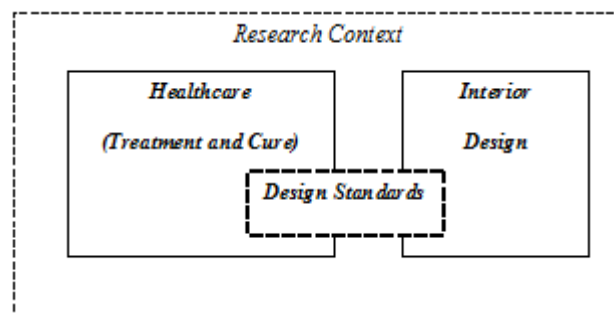

Figure 2: The Main Issues of the Research

Treatment Philosophies and the Interior Environment

According to Leibrock and Cynthia (1991), European and Asian cultures have been historically receptive to holistic healing. Their treatments have incorporated at various times spatherapy, music, nutrition, herbs, vibrational medicine, and colored light. Five elements theory (fire, wood, earth, water, and metal) represents the basis of Chinese medicine. Gerber said that historians have reported healing to have been a highly developed art in Atlantis (9500 B.C.), with three different schools of thought on the treatment of illness. Some healers used spiritual methods using the essence of flowers, crystals, and color therapy; priests used homeopathy, an integration of spiritual and scientific methods; and allopathic healers used herbs, drugs, and surgical treatments similar to the practices of today's orthodox physicians. As new views evolve about the relationship between stress and illness and the influence of positive attitudes on recovery, more emphasis is placed on the design of the patient care environment(Leibrock & Cynthia, 1991).

Formal prescriptions for creating a healing environment are not likely in the near future, but general agreement exists on a broad number of factors known to cause measurable physiological reactions. These factors have to do with noise level, lighting, color, privacy, access to nature, communication with caregivers, and accommodations for family members. Beyond these, numerous studies have explored various theories and variables. The state of research today declares why this field does not have and probably never will have a fixed formula for creating a healing environment(Leibrock & Cynthia, 1991).

Hospital Users and Sustaining the Environment

Hospital design needs to reflect the wide range of users, whether patients, visitors, or staff.

For patients and visitors, entering a hospital is often a stressful and uncertain time. To meet their needs, the required strategy is to provide flexibility in services and to adopt a patient-oriented attitude toward improving the hospital environment (Figure 3). A UK study on improvements in patient recovery found that patients were released one

and a half days earlier in a refurbished environment compared with an unchanged one and time spent in an intensive supervisory care area in a mental health unit was reduced by 70%(Malkin, 2002).

A US research project established four consistent themes in what patients and their families look for in the hospital's built environment(Spohn & Bell, 2009). They want an environment that does the following:

Figure 3: Patients find Landmarks and Décor a Welcome Distraction. These can also Aid Orientation

- Facilitates a connection with the staff.

- Facilitates a connection to the outside world.

- Is conducive to a sense of well-being, homely (particularly in long-term care), attractive, inviting, cheerful, relaxing, with positive distractions.

- Is convenient and accessible, with clear signs and visual clues.

For patients and visitors, color and lighting design can be a welcome distraction (Figure 3). This can be accomplished with careful selection of details, such as décor, landmarks, artwork, skillful interior landscape gardening, and window designs(McLellan, 2014).

The Constructed Environment's Impact on Human Health

Umamaheshwari, Asoka, and Kumaran, (2013) emphasized that the color of a medical environment can have a positive or negative impact on user behavior. Silas, Hansen, and Lent discussed this issue in healthcare facilities, which often include spaces where chemicals are handled. Chemicals exist in medical devices, computers, copy machines, building materials and finishes covering floors, walls, ceilings, and the furniture upon which patients are examined, sit, and sleep. Building occupants are exposed to these chemicals through touching chemically contaminated building and furniture surfaces and through indoor air exposure. The science has linked many of these chemicals to environmental contamination and negative human health effects. When it comes to the indoor environment of healthcare facilities, physicians are primarily concerned about infection control, especially because weakened immune systems are more susceptible to contagious diseases(Franklin et al, 2008; McCullough, 2010; Umamaheshwari, Asoka, & Kuamaran, 2013).

Design Considerations to Reduce Stress and Illness

Positive environmental stimulation can promote patient well-being by reducing stress and negative feelings. If environmental colors can have positive influences, then these colors will make patients more comfortable, reducing their stress (Park, 2009). In 1936, Austrian physician and scientist Hans Selye pioneered revolutionary discoveries about stress. His research demonstrated that hormones released during stress participate in the development of many non-endocrine

degenerative diseases, including brain hemorrhage, hardening of the arteries, coronary thrombosis, certain types of high blood pressure, kidney failure, arthritis, peptic ulcers, and cancer. He gave a new definition to the word *stress,* which had been thought of as an external force. His definition refers to wear and tear on the body from its attempts to cope with environmental stressors (Leibrock & Cynthia, 1991). The effects of stress on the body's structure and chemical composition can be presented by charting the chemical pathways from one organ to another and noting interactions between specific and nonspecific events(Dijkstra, Pieterse, & Pruyn, 2008).

Figure 4: Color should be Considered in All Design Schemes for Patients

The following factors should be considered in the creation of a healing environment(Dalkea et al, 2006), see (Figure 4)

- **Light**

  - No glaring lighting in the patient's room.

  - Ability to control light intensity.

  - Good reading light.

  - Window should be low enough for supine patients to see outdoors.

  - Patient's room lighting should be full spectrum and not less than 300 Lux.

- **Color**

  - Careful use of color to create mood and make rooms cheerful.

  - Use of color in bed linens, gowns, personal hygiene kits, and accessories(see Figure 4)

- **Texture**

  - Textural variety in wall surfaces, floors, ceilings, furniture, fabrics, and artwork.

- **Thermal Comfort**

  - Ability to control room temperature, humidity, and air circulation to suit comfort.

- **Air Quality**

  - Need for fresh air, solarium, or roof garden.

- Avoidance of noxious off-gassing from synthetic materials, including certain types of paint.

- Avoidance of odiferous cleaning agents.

- Adequate air changes per hours.

- **Noise Control**

  - Sounds of footsteps in corridor.

  - Slamming doors, door handle noises.

  - Loudspeaker paging system.

  - Staff conversations in nurse stations or staff lounge.

  - Other patients' televisions and radios.

  - Clatter of dishes on food carts.

- **Views of Nature**

  - Views of nature from patient rooms and lounges.

  - Indoor landscaping.

- **Communication**

  - Ability to contact staff when needed.

  - Comfortable places to visit with family.

  - Television, radio, and telephones available as needed.

- **Accommodation for Families**

  - Placeswhere family members feel welcome.

  - Visitor lounges and access to vending machines, telephones, and the cafeteria.

- **Privacy**

  - Ability to control view of the outdoors.

  - Ability to control social interaction and view of patient in adjacent bed.

  - Secure place for personal belongings.

Color Design

Color design can play an important part in the recovery process and convey sense of well-being (Mazuch, 2000). This section will present some methods for arriving at final color design schemes (Figure 5). These range from clinical guidance on colors for areas dealing with specific medical conditions to the determination of paint colors to be retained in a refurbishment project and incorporated into a new scheme. However, decisions about the colors used in an environment will always remain a personal or subjective issue. Sometimes, individual preferences lead to unpleasant solutions. Creative

color schemes can lead to more stimulating environments, benefiting all users. Malkin,(2002) ensured that the promotion of a greater sense of well-being, particularly in long-term care environments, is possible if the color scheme is carefully planned(Comm & Qual, 1999; Gray et al, 2012).

In all hospital areas, where appropriate, basic color design guidance should be as follows(Coad & Coad, 2008):

Figure 5: Color Design for Interiors

- **Use Tonal Contrast** to provide a difference between adjacent surfaces to enhance visibility for users, especially the elderly or the visually impaired (Figure 5).

- **Provide Tonal Detail** to differentiate architraves, door frames, skirting, and doors from their immediate surroundings through depth (e.g, raised moldings to provide shadow detail).

- **Preserve Existing/Historical Features** of the building that enhance its form. Appropriate materials and features that are important to the building's architectural form should be incorporated into the color palette instead of being altered to fit in with color schemes.

- **Limit the Color Palette** when choosing internal finish materials. Using many different colors can lead to an environment that is too visually busy, leading to confusion and unease (see Figure 5). It can also cause maintenance and storage problems for repair materials.

Figure 6: Applications of Colors

- **Coordinate Paint Colors for Color Harmony.** If possible, try to coordinate the colors of materials such as flooring with other finishing materials used. For example, the color of the floor material could be given to a textile manufacturer so that the color can be incorporated into the curtain designs.

- **Provide continual visual interest with a variety of colors and lighting levels.** This will prevent users from feeling bored due to monotonous visual environments (Gray et al, 2012).

- **Use color and contrast in materials and textures to create surfaces that are tactile, visually stimulating, and which use lighting to maximize shadow detail.**

Color Design and Contrast for the Visually Impaired

Some design applications that can aid the visually impaired and the elderly are given below (Figure 6), since nearly all areas of a hospital will be used by visually impaired or elderly visitors. The following points represent good practice in almost every situation(Stamps, 2011):

- Wall colors should sufficiently differ from the ceiling, floor, and door colors.

- The vertical edges of doors should contrast in color from the rest of the door, since open doors can be very hazardous for the visually impaired.

- Switches, controls, and buttons of any kind should contrast with the walls and hardware.

- Potential obstacles and free-standing objects should be colored so that they stand out from their surroundings (Figure 6).

- There should be a strong contrast between the floor and features above the ground level, such as signage, columns, telephone booths, and literature displays

- Changes in floor gradients or slopes should be visually marked by color and contrast to alert people.

- Strong color contrasts should be used for areas at the approaches to the tops and bottoms of stairs and escalators.

- The side panels of a stairwell should contrast with the stairs to produce a zigzag pattern to aid users descending or ascending the stairs.

- Limit the usage of reflective (mirror-like) surfaces, since they can be detrimental to navigation.

- Use matte floor finishes to aid navigation and reduce reflection and glare from ceiling lights and windows

- Distinguish skirting/floor and skirting/wall junctions with contrasting colors to aid in navigation.

- Handrails that contrast with the walls and attached to the wall at waist height are a good aid. They should be applied to all staircases and could be considered in wards for the elderly.

Color Scheme

As already mentioned, the context, existing materials, and locality will have a big influence on designers' starting point for a colorscheme. The following checklist is a useful starting point(Vincent, Battisto, & McCubbin, 2010):

- Carry out a site audit, both external and internal.

- Identify all accessibility issues inherent in the site's spatial layout.

- Look for areas where contrast is required and where it could improve the environment.

Figure 7: Example of Light and Color Use

Figure 8: Use of a Color Scheme for Navigation

- Define color coding and zoning issues that may affect the scheme.

- Interpret color psychology theories for use within hospital environments.

- Identify the specific ambient requirements of the areas in question (Figure 7).

- Use a limited palette of colors for each area. A large percentage, around 80%, of a pale color is advisable. The palette could include opposite harmonic colors, such as blue and yellow (Read & Upington, 2009; see Figures. 8 and 9).
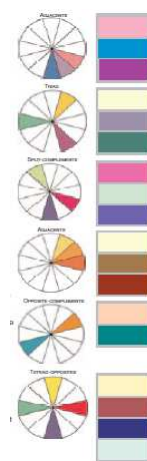
Figure 9: Different Color Schemes

Color Design for Navigation and Signage

Color is not only an aesthetic component of the environment but also a powerful navigational tool to help people

find their way around a building (Figure 8). Since color can aid in recalling shapes and patterns, it is also a vital part of coding and signage if used correctly. On the one hand, navigation covers the following elements(Coad & Coad, 2008):

- **Orientation:** Provision of a sense of direction, course, or point of reference.

- **Way finding:** Information to enable decision making and route planning.

- **Navigation:** Successful negotiation of the building and journey to a destination.

  Also, signage covers the following:

- **Coding:** Provision of a visual system to simplify decision making.

- **Zoning**: Division of a space into broad areas.

- **Signage:** Elements of the environment that provide information for users.

Color Harmony

Harmonious color schemes can be produced with a single hue—such as blue, blue-green, or red-blue—or with a wide variety of colors, as long as there is some scheme for their selection. Color harmony is not based on personal taste; color harmony theories abound and have been developed from the analysis of color circles, philosophers, artists' palettes, and referencing color over many centuries. Color harmony theories have also been adopted in interior color schemes (Figure 9). One approach to a harmonious color scheme might be to use color combinations based on a main hue. A single tonal scheme could include a deep blue for a door, a soft white with the same blue as a pale tint, and a flooring material, such as linoleum, that has a mid-saturation level or the same blue chroma, with dark and light flecks. Alternatively, a scheme could use strong complementary colors in the color circle, for example, a dark blue for the doors and skirting, with a very pale yellow-orange on the walls. The relationship of the pale yellow-orange to the blue provides the harmonious link (opposite complementary)(Stamps, 2011; Vincent, Battisto, &McCubbin, 2010).

Color Psychology

A considerable amount of published material, some empirical and much anecdotal, advises on color application, using theories of color psychology. However, from experience, it is suggested that such publications should not be followed indiscriminately. Contextual variables such as the building materials used in construction, window positions and lighting, size of the space, the proximity of adjacent buildings, or the surface quality of materials can all dramatically affect color appearance and the behavior of color and override color psychology recommendations. These problems can be solved by a well-planned color scheme that bases the colors selected for the building on a wide range of criteria that color psychology theories cannot always cover(Liu et al, 2014; Yildirim, Hidayetoglu, & Capanoglu, 2011). Some guidance is given below and the recommendations on the usage of color should also be applied carefully, since over use of certain colors can cause problems. It is important that color and lighting schemes are developed that enhance the building and create visibly harmonious spaces. *Patient satisfaction* is the new buzzword: It is the difference between providing what a patient *needs* and what a patient *wants.* It is important not only to satisfy clinical needs, but also to meet psychological expectations, which includes comfort and compassionate care (Center, 2014; Verhoeven, Pruyn, & Pieterse, 2006).

**Figure 10: An Adopt A Room suite at the University of Minnesota's Children's
Hospital – Fairview, Minneapolis, Designed by Perkins and Will**

As shown in (Figure 10), the initial vision for the rooms—called Adopt A Room suites, named after the non-profit organization dedicated to upgrading rooms at children's hospitals to a boundary-breaking standard through corporate and private sponsorship—was to make it more inviting, family functional, and livable(Valdez & Mehrabian, 1994). Since it is well documented that noise in hospitals can interfere with patient recovery, lead to stressed and less satisfied healthcare workers, and raise the risk of medical errors, the acoustical design of the room plays a key role in making that vision a reality. The combination of design elements and materials in these suites ensures that every noise that can enter or leave the patient room has been addressed and reduced as much as possible(Spohn & Bell, 2009).

Flexibility is a basic feature of any new healthcare facility to keep it from rapid obsolescence in the face of changing needs and technologies. Healthcare facility needs are evolving rapidly and the direction of that evolution is difficult to forecast with any certainty. New technologies, new treatment methodologies, changes in diseases, and changes in the patient population base all impact healthcare facilities. Inpatient care is steadily being reduced while outpatient services are growing. There is increasing emphasis on special care units and smaller satellite facilities rather than large, centralized facilities. Color, of course, also plays a practical and functional role in patients' accommodations. Used with subtlety in all environments, it can be used to control reflected light, to make the most of available daylight and to help reduce glare(Dalkea et al, 2006).

Sustainability must be a consideration for the design of all healthcare facilities. Many sustainable design features can be incorporated into healthcare facility design, including day lighting, energy and water conservation, nontoxic materials and finishes, and sustainable operations and maintenance(McCullough, 2010). In fact, the greening of the healthcare industry is gaining tremendous momentum and increasing the incorporation of sustainable building.

Benefits of Sustainable Healthcare Design

In the short term, sustainable healthcare design seeks to address the multitude of issues that contribute to the built environment's negative impact on human health. The long-term goal is for buildings to be restorative, contributing positively to the physical, emotional, and even spiritual well-being of occupants. By reducing environmental impacts, healthcare facilities also reduce environmental contaminants. This reduction, in turn, helps decrease the potential for negative health impacts to the surrounding community as the result of toxic waste disposal and incineration, which release these contaminants into the soil and air. An examination of the specific benefits sustainable design offers to a healthcare facility and its occupants shows that many are inextricably intertwined. They include improved patient outcomes, improved patient and staff safety, improved patient and staff satisfaction, better community image and loyalty, greater cost savings, and increased productivity. Improved Patient Outcomes and Safety As an increasing number of sustainable design strategies are introduced in healthcare facilities, a corresponding body of evidence grows to support the idea that green

building practices translate into improved patient outcomes (Heerwagen, 2014).

Improved Staff Safety

Sustainable healthcare design also addresses the issues of staff safety. A first-ever national survey of nurses' exposures to chemicals, pharmaceuticals, and radiation on the job suggests links between serious health problems such as cancer, asthma, miscarriages, and children's birth defects and the duration and intensity of these exposures. At this time, no workplace safety standards have been established to protect nurses from the combined effects of these exposures on their health – through touch, injection, or inhalation. Improved Patient and Staff Satisfaction and Well-Being Numerous studies have demonstrated that building occupants who are in sustainably designed and operated buildings are more satisfied. According to Heerwagen, these effects have been shown to be related to such issues as improved indoor air quality, a connection to the natural environment, access to sunlight and views, and overall improved perception of the work environment. Furthermore, an environmental psychologist and medical models of health integrate behavioral, social, psychological, and mental processes(Victoria, 2014).

The visual environment is formed by the interaction of its physical elements and the light that illuminates it. Thoughtful use of color application can achieve so much in interior design. However, it is the nature of the physical elements and of the illumination together with the interaction between them that will determine its quality. Color has a vital role here in enhancing the environment and providing information and spatial orientation, helping occupants make sense of their surroundings. Aesthetically, it can provide attractive, pleasing conditions for patients, visitors and staff (Victoria, 2014). The application of color and design to patients' accommodation should take account of the emotional and psychological factors which can affect their well-being. This should include the likes and dislikes of user groups of all age groups and cultures. The primary objective is to achieve a friendly and welcoming atmosphere with variety and interest for patients and visitors. The quest for the "correct" color, however, is not as important as devising a scheme which enhances the building, whatever age it is, and thereby creates a harmonious environment. Color does, of course, also have a practical and functional use in patients' accommodation. Used with subtlety in all environments, it can be used to control reflected light, to make the most of available daylight and to help reduce glare. Used with strength, it can also be used for coding and identification purposes(Mazuch, 2000; Vincent, Battisto, & Grimes, 2010; Vincent, Battisto, &McCubbin, 2010)**.**

Sustainable Design Elements and Strategies

A number of critical elements contribute to a sustainable healthcare facility. Indoor air quality, materials and resources, day lighting strategies, connections to nature, cleaning practices, and food service are among them and are discussed in more detail in the following sections. The design, construction, and operations of buildings, in general, use an enormous amount of materials that generate significant byproducts and waste. When designing a facility, considering the type of materials and resources that can reduce the impact of the materials' life cycle is essential(McCullough, 2010).

Historically, common criteria for selecting finishes for a facility include cost, aesthetics, durability, and maintenance, with little or no thought given to a product's life cycle or the impact it will have on the environment and people over its useful life. Though a true life cycle analysis of all materials is difficult (requiring the evaluation of a material's production, transportation, use, and eventual reuse or disposal), some material issues should not be overlooked, such as the impact of materials on indoor air and durability of materials. Also, durable and easy to maintain materials should be selected to reduce waste and prevent unnecessary expenditures for material replacement and

maintenance(McCullough, 2010).

LEED for Healthcare

The LEED for Healthcare Green Building Rating System has been specially formulated to address the design and building challenges concerning healthcare facilities, including inpatient care facilities, licensed outpatient care facilities, and licensed long-term care facilities. LEED for Healthcare can also be used for medical offices, assisted living facilities, and medical education and research centers. It addresses issues such as increased sensitivity to chemicals and pollutants, traveling distances from parking facilities, access to natural spaces, and healthcare operations. LEED for Healthcare builds on the early work of the Green Guide for Health Care (GGHC), which attempted to introduce healthcare–specific aspects to existing LEED rating systems. Working collaboratively with the U.S. Green Building Council (USGBC), GGHC provided expertise in developing LEED for Healthcare, helping streamline LEED for Healthcare's development schedule(Kriss, 2014).

With the introduction of LEED for Healthcare, the GGHC has significantly revised its operations section to emphasize continuous improvement and frame best practices in operations and maintenance protocols, keeping abreast of the momentum in policy and practice toward green building and operations methods and materials(Kriss, 2014).

Figure 11: The Use of Color in Art and Lighting

Revision highlights include the following(Quality, 2008):

- Updated regulatory standards, best practices, and resources,

- An expanded scope that addresses merging priorities in healthcare operations and maintenance,

- An emphasis on continuous improvement and integrated operations and education.

- **Art**: One goal of art is to provide an image offering stress reduction and a tranquil view.

- **Ceiling**: The ceiling should provide a positive distraction or indirect lighting in areas where patients are recovering.

- **Color**: Color perception can impact patients healing.

- **Lighting**: The lamp color temperature is important because it can mute or enhance the color of floor and wall materials (Quality, 2008). (Figure 11, 12)
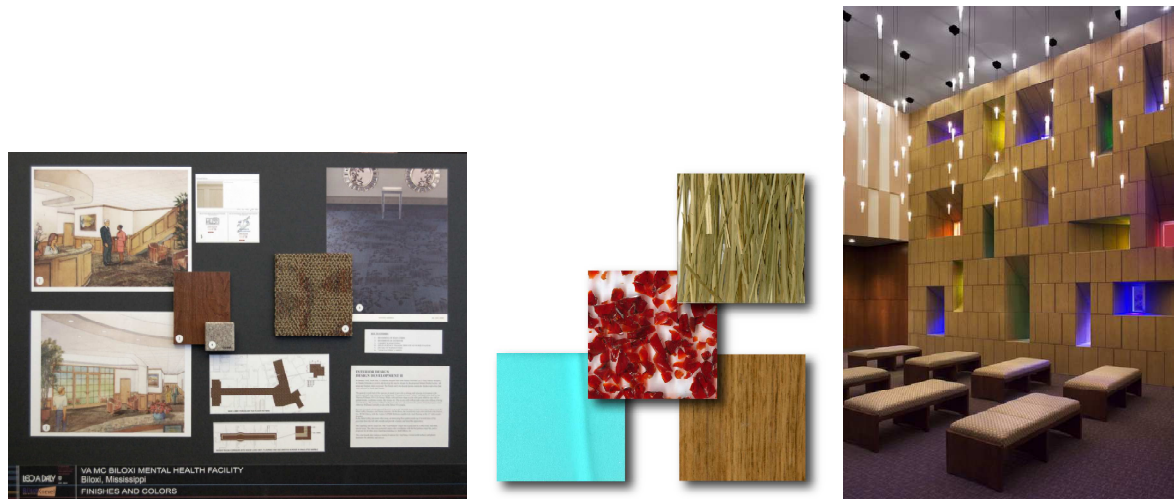
Figure 12: Wall and Ceiling Finishes and Flooring Systems

Interior Design and the Material Selection Process

The following aspects of sustainable design should be explored:

- Recycling content.

- Resource reuse.

- The use of regional materials.

- The use of certified wood.

- Furniture and medical furnishings: resources and reuse.

- Low-emitting materials: adhesives and sealants,

Colors

Color theory is an important aspect in design for patient care. Understanding the appropriateness of colors and applications and how they affect patients is vital. The following critical elements should be considered(Dalkea et al, 2006):

- The impact of color on space.

- Obtaining technical knowledge.

- Acknowledging personal bias.

- Addressing the emotional impact of different color combinations.

- Knowing physical and psychological affects.

5. CASE STUDIES

After reviewing the literature in the preceding section, the research can outline general design considerations used in the interior design of healthcare buildings. The elements of design consideration are addressed in Figure 13. This section is based on the criteria and the design considerations described below. The design considerations will be applied and tested in the following applied analyses to ensure that they match the requirements for treatment and recovery in hospitals'

interior environments. The analyses will be undertaken for three selected rooms in three hospitals at different locations. To achieve a fair comparison of the selected cases, the same analysis was conducted, using the same computer application with the same sequence, which is based on three major steps (see Figure 14):

- Analyzing the current <u>wall color</u> for daylight and the <u>cooling and heating</u> loads.

- Changing the wall <u>colors</u> and analyzing the effect on <u>daylight</u> and cooling and heating loads.

- Choosing the best wall color and then changing window sizes to analyze the changes on the daylight factor and cooling and heating loads.
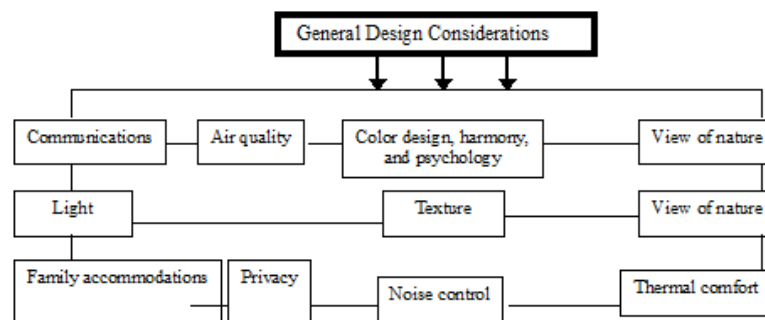
Figure 13: The Applied Research Study Sequence

Figure 14: The Applied Research Study Sequence

A. Dr. Suliman El-Habib Hospital

The selected location for this case study is in Riyadh City as shown in Figure 14. A random room is selected in a simulation process aiming to measure the effect of color change on the daylight factor, a major factor in the physiological well-being of the patient. The selected room is located on the north-east side of the hospital, as shown in Figure 15. The weather data used for Autodesk Ecotect for Riyadh City, was analyzed as shown in Figure 15. All the daylight studies measured the average daylight factor over the year, assuming that the average overcast skylight is 11,000 lux, the window transparency is 90%, and the thermal characteristics of the room are as shown in Figure 16.
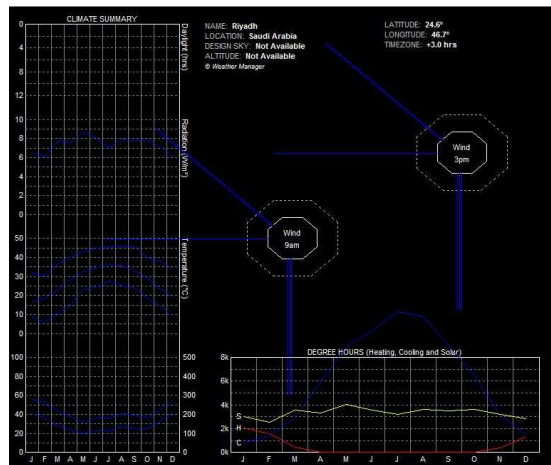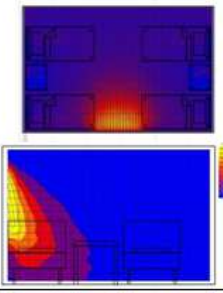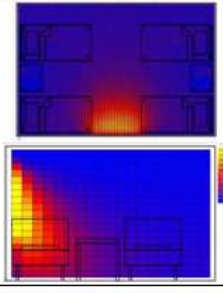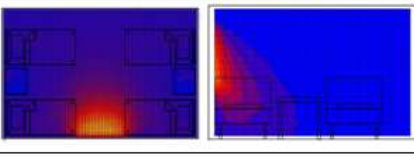
Figure 15: Dr. Suliman El-Habib Hospital and the Selected Room Location
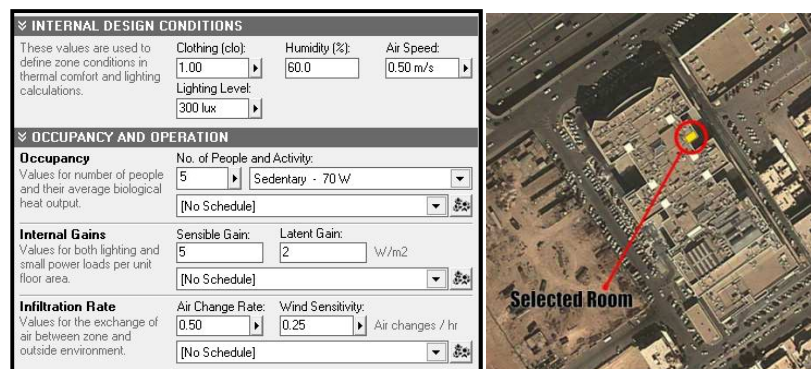
Figure 16: Weather data Analysis for Riyadh City

- **Wall Color Analysis**

Table 1: Wall Color Analysis
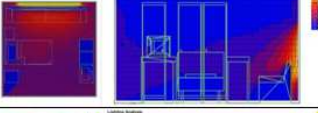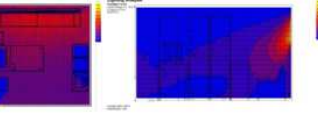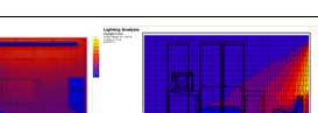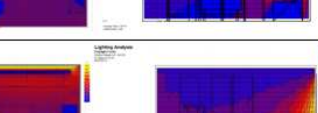
Wall Color	Daylight Factor (%)	Daylight distribution		Cooling and heating loads /KWH
Yellow (237,216,144)	5.89%			7099.9
Green (172,207,107) with surface reflectivity (0.727)	5.21%			7479.5
Blue (172,207,194) with surface reflectivity (0.765)	5.34%			7396.2
Red (217,189,176) with surface reflectivity (0.769)	5.35%			7386.5

- **Window–Wall Ratio (WWR)**

The next step in this analysis is to choose the best case in Table 1, which is yellow walls, and then change the

WWR to the requirements of patient rooms. The results for the daylight factors, cooling, and heating loads are then compared for each case.

Table 2: WWR Analysis

WWR	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
32% (current case)	5.89%		7099.9
20%	4.86%		6968.5
50%	7.64 %		7493.8
80%	9.8%		8029.5

B. King Fahd Hospital

The selected case study is located in Riyadh (24. 6°, 46.7°), as shown in Figure 17. A random room is simulated to measure the effect of room color change on the daylight factor. The selected room is located on the north-east side of the hospital, as shown on Figure 17. The weather data used for Autodesk Ecotect for Riyadh City was analyzed as shown on Figure 18. All the daylight studies measured the average daylight factor over the year, assuming that the average overcast skylight is 11,000 lux, the window transparency is 90%, and the thermal characteristics of the room are as shown in Figure 18.
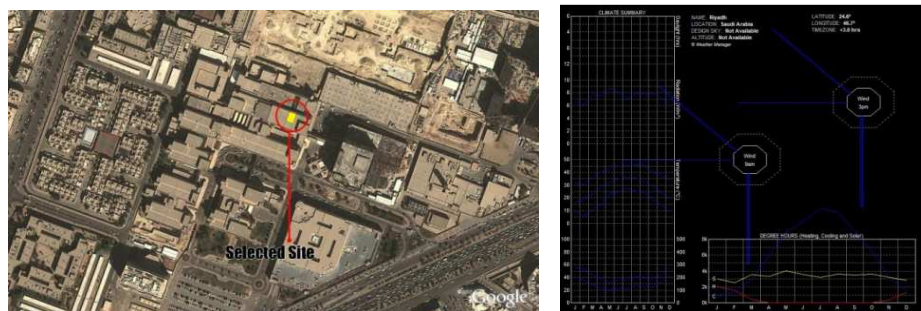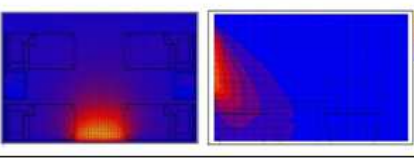
Figure 17: Weather Data Analysis for Riyadh City for the Second Case

Figure 18: Weather Data Analysis for Riyadh City for the Third Case
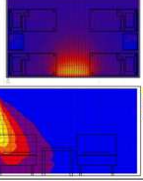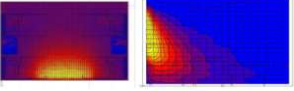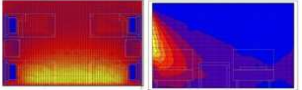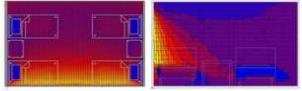
- **Wall Color Analysis**

Table 3: Wall Color Analysis

Wall Color	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
Silver (241,241,241) with surface reflectivity (0.945), current case	3.41%		6238.1
Green (196,228,161) with surface reflectivity (0.828)	3.09%		6366.3
Blue (196,212,222) with surface reflectivity (0.817)	3.07%		6360.2
Red (137,118,111) with surface reflectivity (0.482)	2.54%		6345.1

- **WWR**

Table 4: WWR Analysis

Wall Color	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
13.3% current case	3.41%		6238.1
20%	6.9 %		6835.4
50%	9.24 %		7272.1
80%	11.4 %		8575.6

C. Children's Hospitals and Clinics of Minnesota

Figure 19: Case Study Location, Minneapolis, MN

The selected case study is located in Minneapolis, Minnesota (44.9°, -93.2°), as shown in Figure 19. A random room is selected and simulated to measure the effect of room color change on the daylight factor. The room is located on the north side of the hospital, as shown in Figure 19. The weather data used for Autodesk Ecotect for Minneapolis, MN, was analyzed as shown in Figure 20. All the daylight studies measured the average daylight factor over the year, assuming that the average overcast skylight is 8500 lux and the window transparency is 90%, with the thermal characteristics of the room as shown in Figure 20.
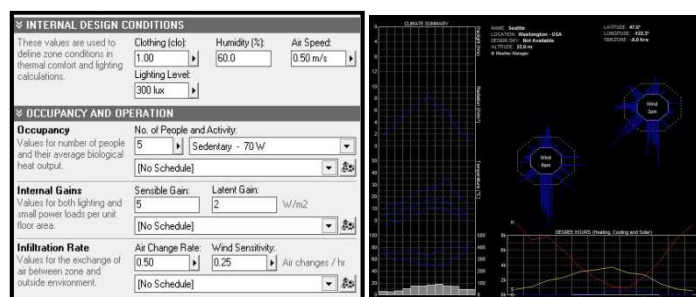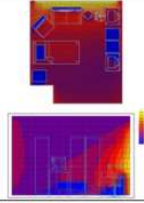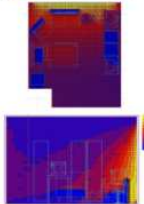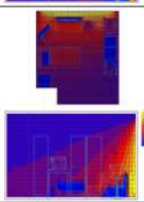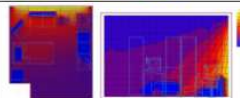

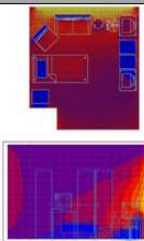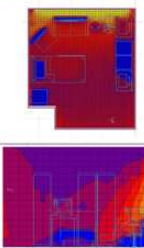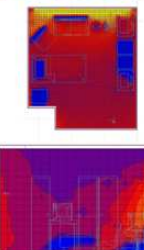**Figure 20: Weather Data Analysis for Minneapolis, MN**

- **Wall Color Analysis**

Table 5: Wall Color Analysis at the Children's Hospitals of Minnesota

Wall Color	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
Yellow (216,216,178) with surface reflectivity (0.831), current case	14.03 %		5903.5
Green (170,221,173) with surface reflectivity(0.786)	12.41%		5810.4
Red (233,156,128) with surface reflectivity(0.690)	11.67%		5760.7
Blue (165,185,243) with surface reflectivity(0.727)	11.87%		5779.5
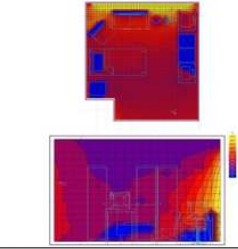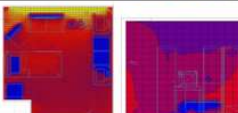
Ground Color Analysis

Table 6: Ground Color Analysis at the Children's Hospitals of Minnesota

Ground Color	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
Yellow (216,216,178) with surface reflectivity(0.831)	14.03 %		5903.5
Green (158,233,159) with surface reflectivity(0.794)	15.71%		5853.4
Silver (212,212,212) with surface reflectivity(0.831), current case	16.09%		5730.6

Furniture Color Analysis

Table 7: Furniture Color Analysis at the Children's Hospitals of Minnesota

Furniture Color	Daylight Factor (%)	Daylight Distribution	Cooling and Heating Loads /KWH
Yellow, current case	16.09%		5730.6
Green sofa + white bed + blue chair	16.45%		5713.2

6. RESULTS

The paper aims to show that the concept of hospital interior design is different than that of other buildings. The selection of color, floors, ceilings, walls, furniture, and lighting has a great impact on the well-being of patients and the medical staff. Therefore, selection is based on certain criteria, specifications, and strong scientific evidence that takeinto consideration not only the psychological and physiological impacts but also the aesthetic effects on the building occupants. Table 8is an example of the design considerations of color sustainability that can be applied to hospital interior spaces to determine if general healthcare requirements can be achieved.

Table 8: Design Considerations of Color Sustainability at Hospitals

Design Considerations	Healthcare (Treatment and Recovery) Requirements				
	Environment	Stress and Illness Reduction	Psychology	Flexibility	Safety
1. Color design	√	√√√	√√	√	√√√
2. Texture	√√√	√√√	√√√	√√√	√√√
3. Thermal comfort	√√√	√√√	√√	√	√√√
4. Light	√√	√√√	√√√	√√√	√√√
5. Air quality	√√√	√√√	√√√	√	√√
6. Noise Control	√√	√	√√√	√√√	√√√
7. Nature views	√√√	√√	√√√	√√√	√√
8. Communications	√	√√√	√√√	√√	√√√
9. Family accommodation	√√	√√√	√√√	√√	√
10. Privacy	√√	√	√√	√√√	√√

7. CONCLUSIONS

Color plays a major role in setting a particular mood or state of mind. Color affects one's feelings, moods, and emotions. The use of color has long been one of the most subjective aspects of interior design, especially in healthcare settings. This may account for the fact that many of the newer hospitals are devoid of color. For those who seek validation through evidence-based research, it is very difficult to design color studies for the actual setting of a healthcare facility; therefore, there is little that is definitive in the way that practitioners might wish to find clear principles that can be applied to the healthcare environment. Nevertheless, there is much value in the assembly of studies noted in this paper to enable the confident practitioner, armed with basic color theory, to understand the sensitivities of each type. With respect to sustainability, the paper addresses the relationship between the design of interior space colors and the lighting of hospitals and users' psychological and physiological aspects to serve adults. Furthermore, the paper encourages a thorough understanding about where, when, and how color can impact the healthcare experience. It presents the best summary to date of studies on color and encourages further research.

ACKNOWLEDGEMENTS

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